Radiographic Diagnosis of Dental Caries

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Abstract:

The purpose of this report was to respond to aspects of the RTI/UNC systematic review relating to the radiographic diagnosis of dental caries. The systematic review was commissioned as part of the NIH Consensus Development Conference on Diagnosis and Management of Dental Caries Throughout Life. The systematic review evaluated the dental literature from 1966 to 1999. Well-defined search criteria along with clear inclusion and exclusion criteria were used to perform the review. Some of the inclusion and exclusion criteria used in the systematic review may have limited the evidence supporting the use of radiography, especially for the diagnosis of proximal surface caries. The RTI/UNC review only included studies in which sensitivity and specificity were reported or could be derived from the data presented. Studies which used the receiver operating characteristic as a measure of diagnostic accuracy were not included. Although the strength of evidence is considered poor, this does not mean that the use of radiographic methods is of no diagnostic value. It simply means that, using the criteria established by the systematic review, the evidence is inadequate to validate the method. Guidelines should be developed for assessing diagnostic methods that assist researchers in developing study designs that will hold up to critical review.

Keywords: dental caries, caries diagnosis, dental radiology, dental radiography, oral diagnosis

Almost since the discovery of x-rays by Wilhelm Conrad Roentgen in 1895, radiography has been used to detect the effects of dental caries on dental hard tissues. Radiography has been primarily used for the detection of lesions on the proximal surfaces of teeth, which are not clinically visible for inspection. Radiographs are also recommended as a supplement to the clinical examination of occlusal surfaces for the detection of pit and fissure caries. Over the years it has been well established that more dental caries is detected by radiography than by clinical examination alone.[1-6]

Radiographic diagnosis of dental caries is fundamentally based on the fact that as the caries process proceeds, the mineral content of enamel and dentin decreases with a resultant decrease in the attenuation of the x-ray beam as it passes through the teeth. This is recorded on the image receptor as an increase in radiographic density. This increase in radiographic density must be detected by the clinician as a sign of a carious lesion. Many different factors can affect the ability to accurately detect these lesions such as exposure parameters, type of image receptor, image processing, display system, viewing conditions and ultimately the training and experience of the human observer.

A systematic review of the existing literature was performed by the RTI/UNC Evidence Based Practice Center to address the question of the validity of six different diagnostic methods for the detection of dental caries in primary and permanent teeth. The diagnostic methods assessed included: visual and visual/tactile inspection, radiography, fiber-optic transillumination (FOTI), electrical conductance (EC), laser fluorescence (LF) and combinations of these methods.

Three primary computer indexes used in searching the literature were MEDLINE, EMBASE and the Cochrane controlled trials register. The period searched was from January 1966 to December 1999. Inclusion and exclusion criteria were clearly defined prior to performing the search. Studies were limited to those with human subjects and natural carious lesions, publication language in English, histological validation of caries status for each surface studied

or visual/tactile validation of intact surface for cavitation only; outcomes must be expressed as sensitivity and specificity or provided data from which these outcomes could be derived. While both *in vitro* and *in vivo* studies were included in the review, only those methods that are commercially available to the general practitioner were assessed.

Thirty-nine studies were selected from among 1,407 diagnostic reports that satisfied all criteria. These studies reported 126 different assessments of different diagnostic methods. Of these studies, 65 assessements evaluated the diagnostic performance of radiographic methods. The studies were critically reviewed and a quality rating scale assessed, which appraised several elements of internal validity, including study design, duration, sample size, blinding of examiners, baseline assessments and examiner reliability. The overall strength of evidence supporting the validity of a method was judged in terms of the extent to which it offered clear, unambiguous assessment of a particular method for identifying a specific type of lesion on a specific type of surface.

Some of the inclusion and exclusion criteria used in the systematic review may have limited the evidence supporting the use of radiography, especially for the diagnosis of proximal surface caries. The RTI/UNC review only included studies in which sensitivity and specificity were reported or could be derived from the data presented. Studies which used the receiver operating characteristic as a measure of diagnostic accuracy were not included.

Receiver Operating Characteristic (ROC) analysis is a method to determine the diagnostic accuracy of a particular method of assessment. ROC is based upon signal detection theory and provides for an unbiased measure of discrimination in the paired-comparison or forced-choice situation.[7] This is exactly the type of choice the dentist faces when determining the presence or absence of a carious lesion on a radiograph. Using sensitivity and specificity values for a diagnostic test or imaging modality can be ambiguous as dentists exhibit a wide variation in their decision criteria.[8] The ROC analysis gives a measure of discrimination that is independent of the

cut-off points of the decision criterion and, therefore, unbiased by them.[7] Recently, many researchers evaluating the diagnostic performance of radiographic methods have advocated the use of ROC analysis to evaluate imaging systems for the diagnosis of dental caries.[9] A search of the Medline database from January 1966 – December 2000 using [exp dental caries/ or dental caries.mp. (21,172)] and [exp radiography/ or dental radiology.mp. or exp radiography, dental, digital/ or exp radiographic image enhancement (101,704)] and [exp ROC curve/ or ROC curve.mp. (2,167)] as search criteria resulted in 62 reports. Including these studies may have improved the strength of evidence for radiographic methods for the detection of dental caries.

Another criteria used for inclusion also had a significant effect on the overall outcome of the assessment. Studies included were required to have histological validation of caries status for each surface studied. Some exceptions were made with regard to those studies where cavitation was the extent of lesions to be detected. Due to the practical and ethical limitations of obtaining histological confirmation, the majority of assessments were *in vitro* (6 *in vivo* and 59 *in vitro*). In the determination of a quality rating, the maximum score for experimental setting was 20 points. Considering that an *in vitro* study was given a score of zero and an *in vivo* study was given a score of two for experimental setting, 10 percent of the overall quality score was affected by this criterion. While some of the methods such as visual inspection, fiber-optic transillumination and electric conductance can be greatly affected by the setting in which they were performed, the basic physics of image formation should not be greatly affected by difference between a laboratory and clinical setting provided extracted human teeth and natural caries are being studied. A meta-analysis of factors involved in the validity of radiographic diagnosis for proximal surface caries indicated that experimental setting did in fact have an impact on diagnostic performance.[10] Contrary to the results of this meta-analysis, a more recent direct experimental examination of the same question supports the idea that no such relationship exists. Hintze and Wenzel[11] directly compared the diagnostic accuracy of radiographs obtained both *in*

vivo and *in vitro* of the same teeth for the detection of occlusal and proximal surface caries. The results of their study suggest that no difference could be found between *in vivo* and *in vitro* results using receiver operating characteristic (ROC) anaylsis.

The RTI/UNC systematic review of the dental literature indicates that the strength of evidence for radiographic methods for the detection of dental caries is ***poor*** for all types of lesions on posterior proximal and occlusal surfaces. This was primarily due to the large amount of variation in the reported sensitivity and specificity of this method. Little if any evidence exists to support the use of radiographic methods for primary teeth, anterior teeth and root surfaces. The literature is severely limited by problems associated with both internal and external validity. These include: incomplete descriptions of sample selection, diagnostic criteria and examiner reliability, the use of small numbers of examiners, non-representative teeth, samples with high lesion prevalence and the use of reference standards of questionable reliability.

Although the strength of evidence is considered poor, this does not mean that the use of radiographic methods is of no diagnostic value. It simple means that using the criteria established to evaluate the existing evidence, the evidence is inadequate to validate the method. Better studies designed to address the limitations of the current literature could in fact indicate that the method is valid. It does call into question the relative importance of this method in making treatment decisions.

A review of the RTI/UNC report indicates that most of the variability in diagnostic performance of posterior proximal and occlusal surfaces was in fact associated with the sensitivity of the method and not the specificity. Table 1 shows the radiographic assessments of the diagnosis of cavitated lesions, lesions involving dentin and any lesions on proximal surfaces of posterior teeth. For those assessments involving cavitated lesions the standard deviation of the mean sensitivity was 0.21, whereas the standard deviation of the mean specificity was only

0.04 (Table 1). This same trend is consistent for all evaluations of proximal surfaces regardless of lesion progression. This trend is not apparent when considering the diagnosis of occlusal caries involving dentin (Table 2). However, the variability in sensitivity is high when compared to that of specificity when evaluating the occlusal surfaces of permanent posterior that had lesions of different depths (Table 2). On further review considerable outliers appear in each dataset. These have been indicated in **bold** font. Some of the variability may be explained by the detection task itself and the decision criteria used by different evaluators. When performing radiographic interpretation the decisions are presented as either the presence or absence of a lesion. But the decisions are not always so black-and-white, but in fact lie in a gray continuum of negative to positive. Therefore, several different values along this continuum could be selected as a cut-off to determine if dental caries is present or absent. Depending upon whether more stringent or more lenient criteria are used for detection, the sensitivity and specificity can vary dramatically. If more stringent criteria are applied, fewer false-positives will occur resulting in higher specificity at the expense of sensitivity and the associated increase in false-negative decisions. If however, more lenient criteria are used the inverse is typically true.

All of the evidence suggests that radiographic methods have a higher degree of specificity than sensitivity, which means that false-negative diagnoses are proportionally more apt to occur in the presence of disease than are false-positive diagnoses in the absence of disease. This outcome may be beneficial if the negative consequence of a false-positive diagnosis outweigh that of a false-negative diagnosis. Currently the most common type of intervention is surgical removal of the lesion, a false-positive diagnosis results in a perfectly normal tooth being irreversibly damaged. A false-negative results in further progression of the lesion and potentially further loss of tooth tissue. This outcome is somewhat abated by the fact that the lesion may be detected at a later time. Non-surgical interventions are gaining in popularity as alternatives to mechanical replacement of damaged tooth tissue with artificial materials. These non-surgical

methods are only effective if the lesion is detected prior to cavitation. This means that the lesion must be detected early. To detect the lesion earlier, a diagnostic method must provide for higher sensitivity, which may result in more false-positive diagnoses. If early interventions consist of non-surgical management, which does not result in any permanent damage to the tooth, then the negative consequence of a false-negative diagnosis outweigh that of a false-positive diagnosis. Every attempt should be made to increase the sensitivity of currently available methods of radiographic diagnosis to coincide with this change in intervention strategy.

New digital radiographic techniques that eliminate the use of silver halide emulsion x-ray film by capturing radiographic images on photostimulable phosphor imaging plates or charge-coupled devices may improve detection of dental caries. The images acquired with these technologies are digital and can be processed or analyzed to enhance diagnostic performance. The weight of available evidence suggests that the use of some digital methods offers small gains in sensitivity without reduction in specificity, and that image analysis techniques may offer more substantial gains.

Renewed effort should be made to ensure that future studies address the question of diagnostic validity adequately. Guidelines should be developed for assessing diagnostic methods that assist researchers in developing study designs that will hold up to critical review.

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